Measurement of the Top Quark Pairs Production Cross Section at DØ Using e/μ + track Events

Outline

- Top Quark
- Why e/μ + track mode?
- Signal Events Selection
- Backgrounds
- Cross Section

APS 2006, August 22-25, Dallas (Texas)

Dmitri Denisov, Fermilab

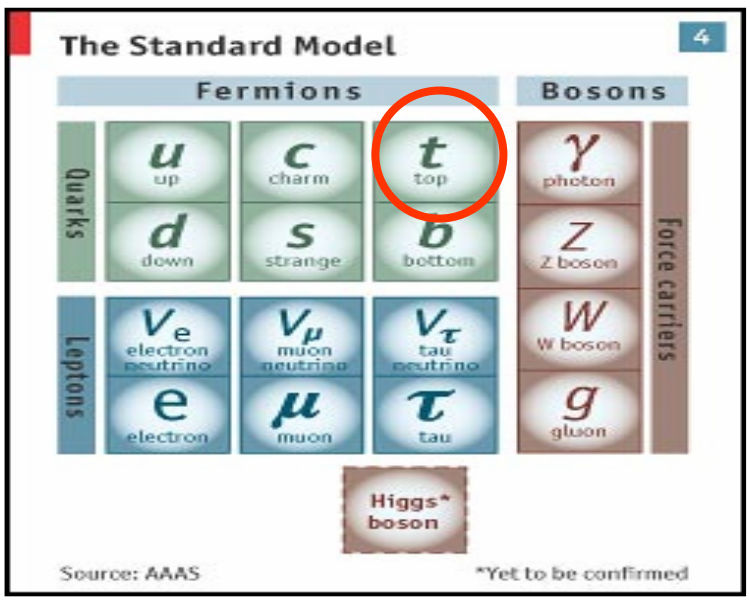
For the DØ Collaboration

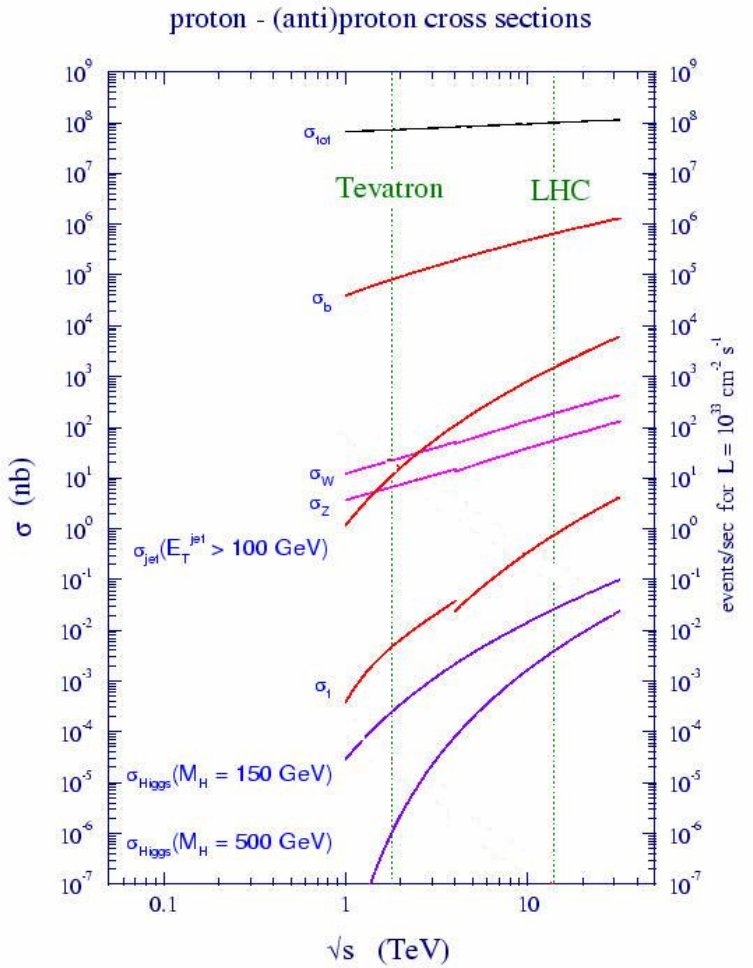
Top Quark Studies at DØ

Discovery of top quark at Fermilab in 1995
- Completed Standard Model quark sector

Studies of heaviest known elementary particle provide
- Standard Model parameters, tests
- Beyond Standard Model searches

Experimental challenges: 175 GeV mass, low cross sections and high backgrounds
- Accelerator - Tevatron is the only "top factory" with $\sqrt{s}$ =1.96TeV
- Detector
- Analysis



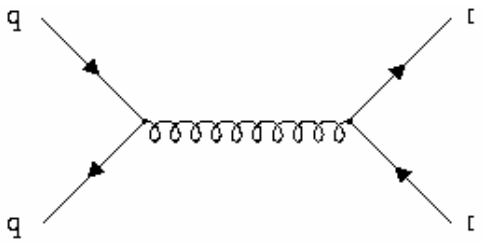


Top quark pairs production cross section measurements *test*
- QCD predictions for highest mass quark
- SM predictions for top quark decays
- Methods of top quark identification

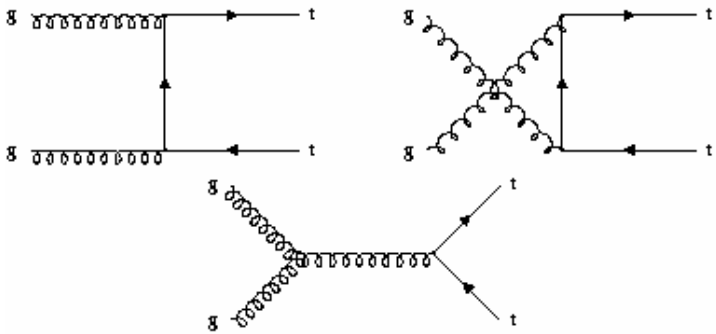
Top Quark Production and Decays

Production

Top quarks at Tevatron are (mainly) produced in pairs via strong interaction



85%

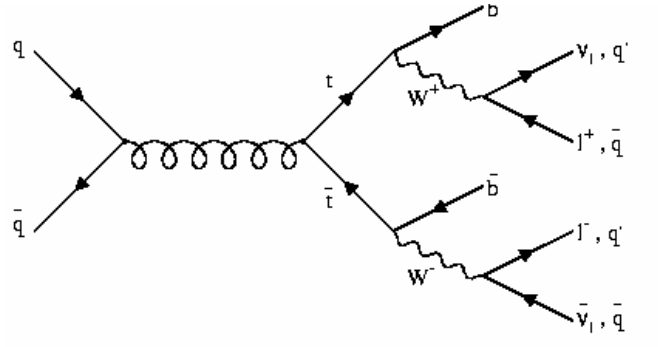


15%

NLO QCD prediction for top quarks pair cross section at $\sqrt{s}$=1.96 TeV is 6.7 $\pm$ 0.7pb

Decay

In SM top lifetime is very short
Decays 100% to **W+b**



%	*eν*	*μν*	*τν*	*qq*
eν	1.2	2.5	2.5	14.8
μν		1.2	2.5	14.8
τν			1.2	14.8
qq				44.4

Top decays classification: di-lepton, lepton+jets, all jets

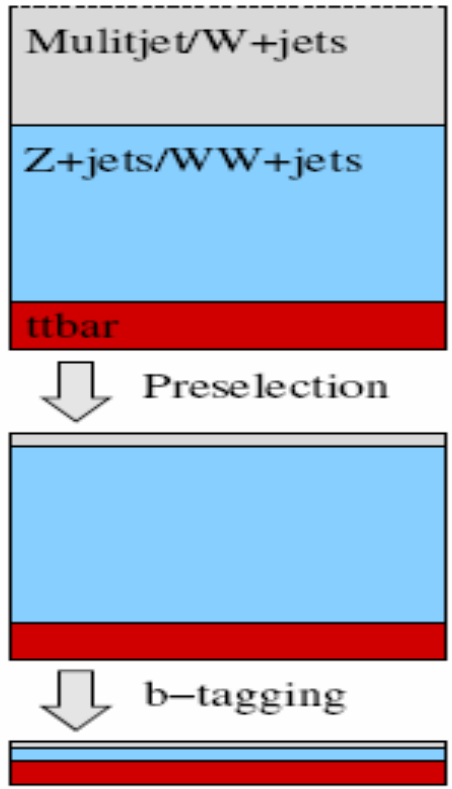
Why e/μ + track Mode?

- **Di-lepton final state**
  - Cleanest = lowest backgrounds
    - Two high P_t leptons
    - Two high energy jets
    - Large missing E_t from two neutrinos
  - But branching fraction is 5%…

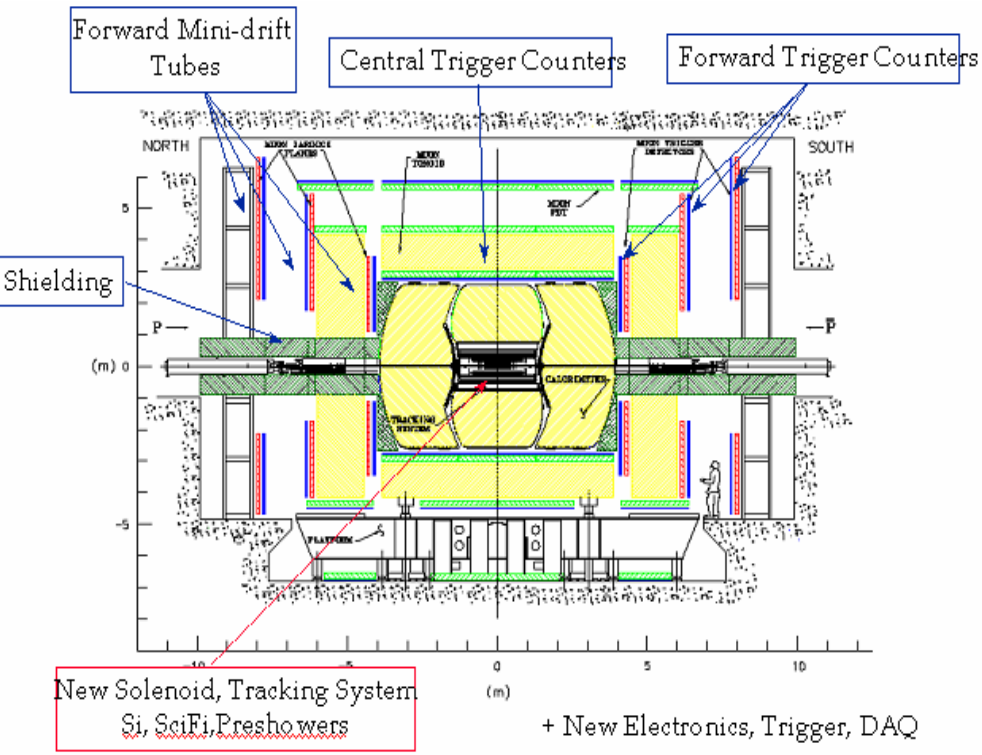
- With ~7pb cross section in ~0.4fb^{-1} data set
  - ~3 ·10^2 top pairs produced with decay to di-lepton channel
- But… events selection efficiencies are "low", providing opportunity to detect a few % of created events
  - ~3 ·10^2 → ~10 events

Events losses in di-lepton channel
- 2nd power of e/μ efficiencies
- Holes in muon detector and calorimeter acceptance

Idea – select events with
- One lepton and one track (both high P_t, isolated), missing E_t, high energy jet(s)
- Tag b quark jet to reduce backgrounds



DØ Experiment in Run II and Data Set



New for Tevatron Run II

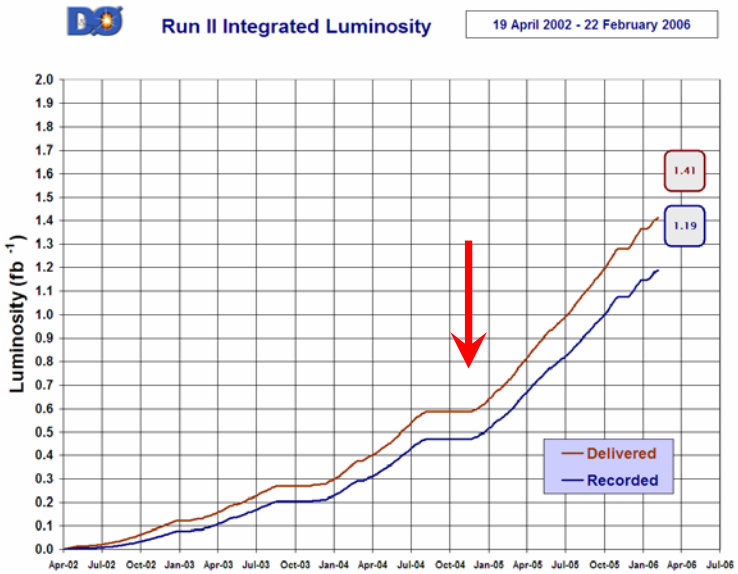
- Silicon detector
- 2 T solenoid and central fiber tracker
- Substantially upgraded muon system
- New electronics

Still there are acceptance "holes"

- Supports, access gaps, limited rapidity coverage, etc.

Data set

- 2002-2004 data taking
- Ldt ~ 370 pb^{-1}

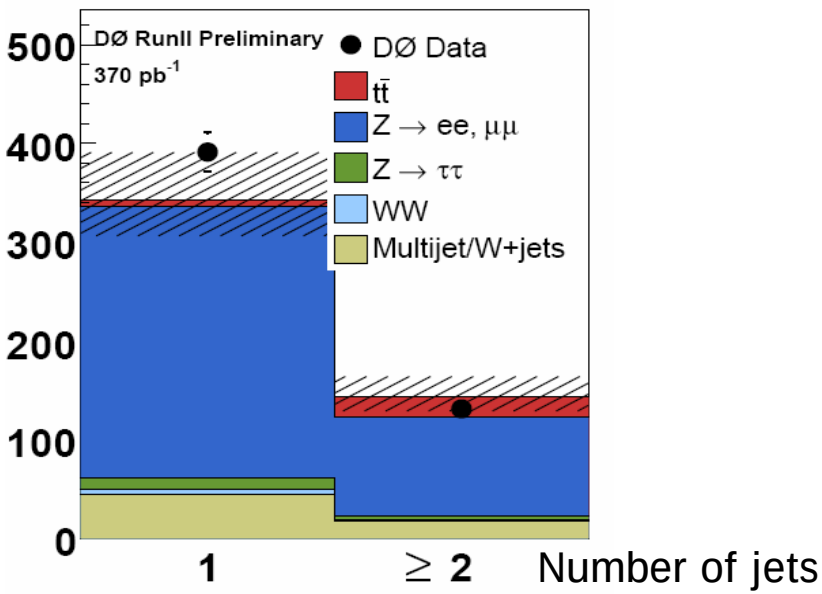


Cross Section Ingredients

$$\sigma_{t\bar{t}} = \frac{N_{obs} - N_{Bkg}}{\epsilon \int Ldt}$$ → four main numbers needed

- 370 pb^{-1} of "good quality" data
- High P_t multi-level single e/μ and e/μ with jet triggers
- Topological event selection
  - One isolated e/μ with P_t>15GeV
  - One isolated track with P_t>15GeV
  - Missing E_t of 15-35GeV
  - >= one E_t>20GeV jet
- If track matches identified e/μ, then event is not analyzed
  - Covered in eμ di-muon analysis (Burke's talk) with softer cuts (no Z+jets background)
  - Keep two analyses un-correlated for easy averaging

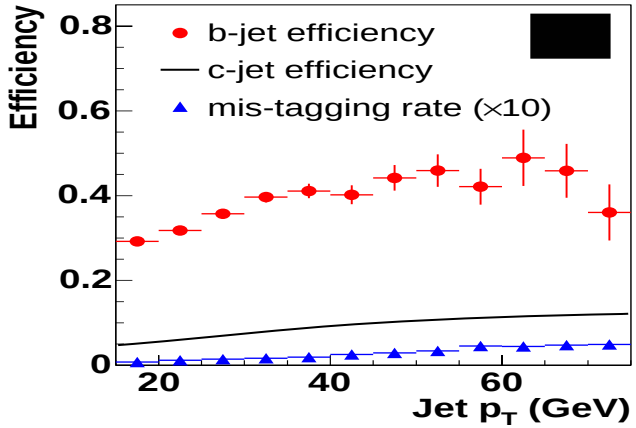
- Simulation of signal and background
  - ALPGEN1.2+PYTHIA6.2+GEANT
  - 175 GeV top quark mass used



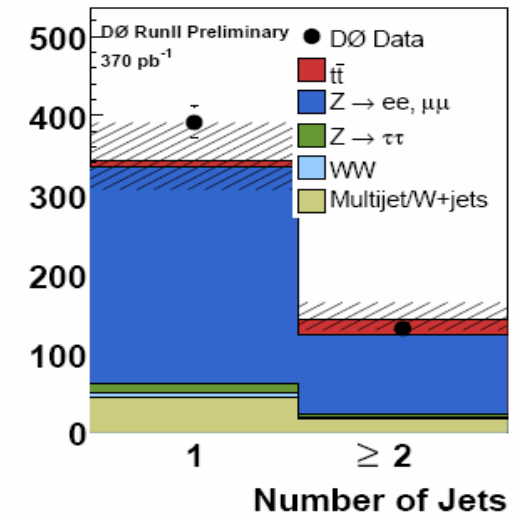
Backgrounds are well understood, but too high...

Adding b-tagging

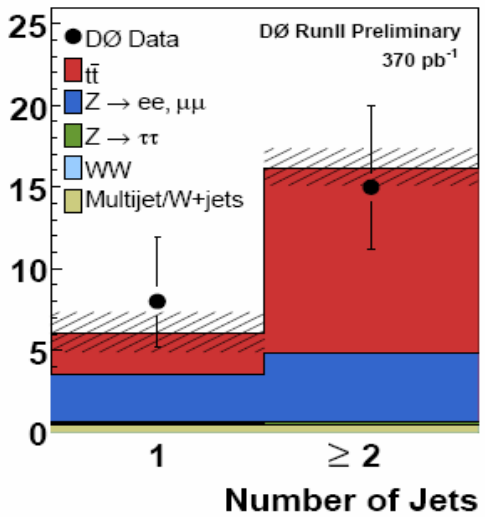
- Two high E_t jets in top pairs final decay products are jets originated from b quarks fragmentation
  - Lifetime of B meson is ~0.5mm
  - Require 7σ displaced vertex significance
- Tagging at least one jet in an event reduces Z+jets backgrounds (light quarks), keeping substantial number of top events



- Jet b-tagging efficiency is measured from data using semi-leptonic b decays
- Probability to tag light quark jet (mistag rate) is calculated using QCD multi-jet sample



b−tagging



Clear top signal!

Final Cross Section Calculation

$$\sigma_{t\bar{t}} = \frac{N_{obs} - N_{Bkg}}{\epsilon \int L dt}$$

	Electron+track		Muon+track	
Number of jets	1	≥ 2	1	≥ 2
	Expected number of events			
WW	0.037 ± 0.002	0.010 ± 0.002	0.016 ± 0.001	0.009 ± 0.002
$Z/\gamma^* \rightarrow \tau\tau$	0.09 ± 0.02	0.13 ± 0.02	0.03 ± 0.01	0.09 ± 0.02
$Z/\gamma^* \rightarrow ee, \mu\mu$	1.49 ± 0.04	2.35 ± 0.06	1.44 ± 0.04	1.86 ± 0.06
Multijet/W+jets	0.36 ± 0.06	0.35 ± 0.07	0.08 ± 0.02	0.05 ± 0.03
Total background	$\mathbf{1.97 \pm 0.08}$	$\mathbf{2.83 \pm 0.09}$	$\mathbf{1.57 \pm 0.05}$	$\mathbf{2.00 \pm 0.07}$
Tot. unc. (stat+syst)	$+0.91\ -0.85$	$+0.87\ -0.64$	$+0.77\ -0.77$	$+0.51\ -0.49$
$t\bar{t}$	1.55 ± 0.03	6.59 ± 0.07	0.92 ± 0.02	4.74 ± 0.06
Signal + background	$\mathbf{3.53 \pm 0.08}$	$\mathbf{9.4 \pm 0.1}$	$\mathbf{2.49 \pm 0.05}$	$\mathbf{6.74 \pm 0.09}$
Tot. unc. (stat+syst)	$+0.99\ -0.86$	$+0.99\ -0.85$	$+0.83\ -0.77$	$+0.67\ -0.64$
	Observed number of events			
Data	**7**	**9**	**1**	**6**

$$\sigma_{t\bar{t}}^{l+track} = 7.1\ ^{+2.6}_{-2.2}\ (\text{stat})\ ^{+1.3}_{-1.3}\ (\text{syst})\ \pm 0.5\ (\text{lumi})\ \text{pb}$$

Comparison: ~14 signal events expected vs ~7 events in di-lepton ee/μμ channel – added "extra" top events to the analysis!

Combination with eμ di-lepton Channel

Combination with eμ topological analysis without b tagging (Burke's talk)

Powerful way of combining channels as many systematic uncertainties are uncorrelated

Combined cross section

$$\sigma_{t\bar{t}}^{l+track+e\mu} = 8.6\ ^{+1.9}_{-1.7}\ (\text{stat})\ ^{+1.1}_{-1.1}\ (\text{syst})\ \pm 0.6\ (\text{lumi})\ \text{pb}$$

Summary of e/μ + track Top Quark Cross Section Measurement

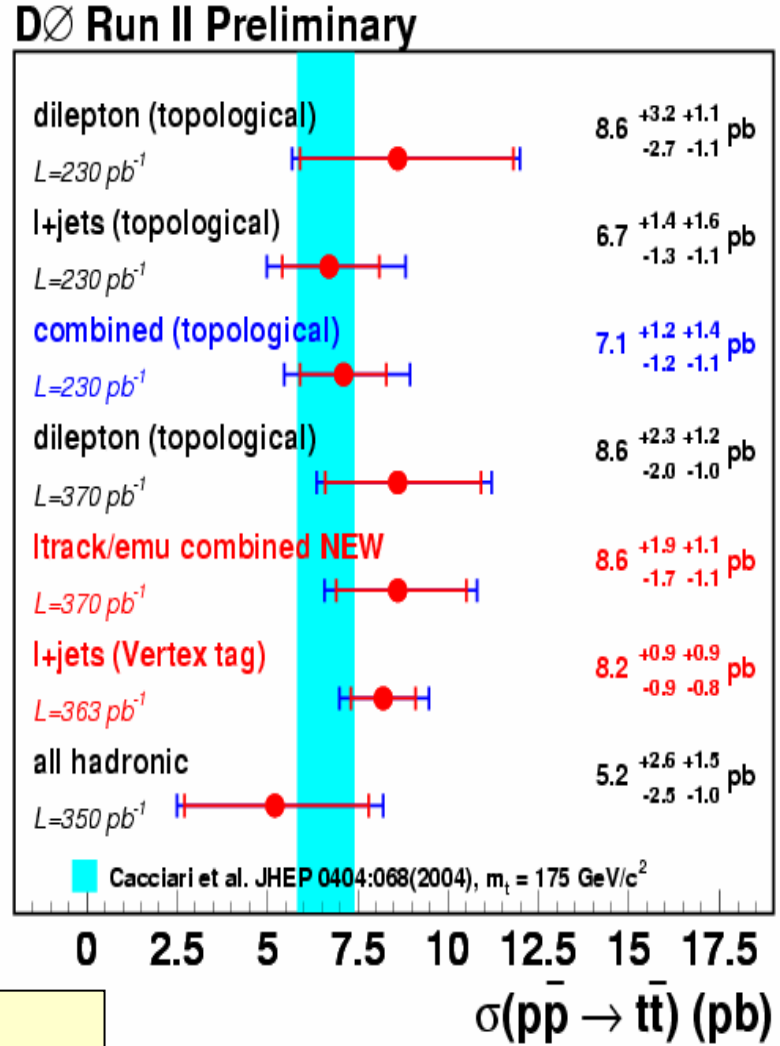
e/μ+track method of top quark pairs production cross section measurement is developed at DØ

Using e/μ+track and eμ di-lepton events top pairs cross section at √s=1.96TeV is measured to be

$$\sigma_{t\bar{t}}^{l+track+e\mu} = 8.6\ ^{+1.9}_{-1.7}\,(\text{stat})\ ^{+1.1}_{-1.1}\,(\text{syst}) \pm 0.6\,(\text{lumi})\ \text{pb}$$

Cross section is in agreement with QCD predictions and measurements in other modes of top quark decays

Standard Model works! (for now…)



Measurement is statistically limited
It will improve with Tevatron delivered luminosity increase